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Using INL Capabilities to Support Meeting the Needs for HALEU

John C Wagner

October 2018

The INL is a U.S. Department of Energy National Laboratory
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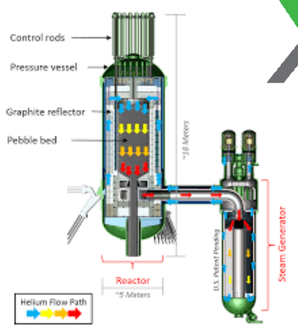
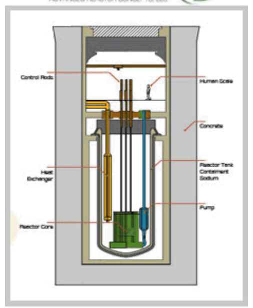
October 10, 2018
LINE Commission, McCall, Idaho

National Reactor Innovation Center is being established at INL

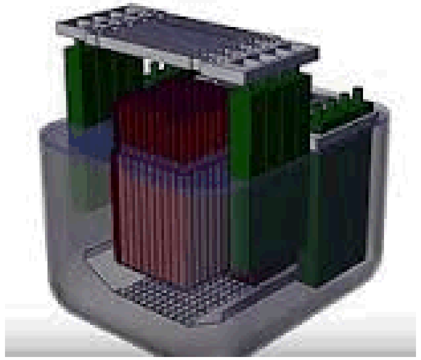
- **Enable the deployment of new nuclear systems by using INL's unique infrastructure and expertise to resolve the basic R&D challenges confronting the most promising advanced reactor concepts.**
  - Fuels and core designs that improve the economics of current operating nuclear power plants
  - Demonstration and first-of-a-kind deployment of new reactor concepts:
    - Advanced small-modular light water reactors
    - Advanced non-light water reactors
    - Microreactors
  - Development of fuel cycle infrastructure



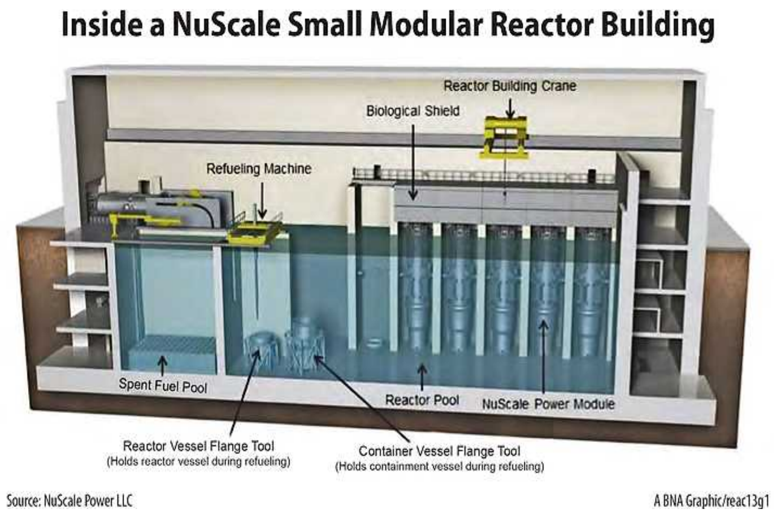
Xe-100 200 MWt PBR



ARC-100, MWe



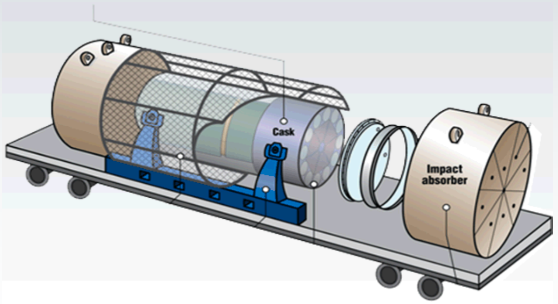
150-1500 MWe, Moltex



Vision for Advanced Reactor Pipeline

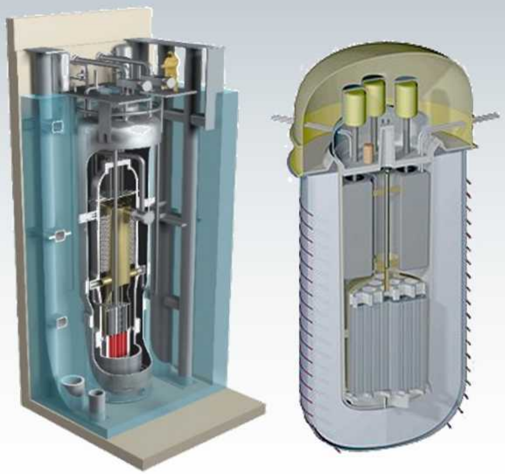
Demonstrate first <10MW micro-reactor by 2021

- Resolve advanced reactor issues
- Open new markets for nuclear energy
- Provide a 'win' to build positive momentum



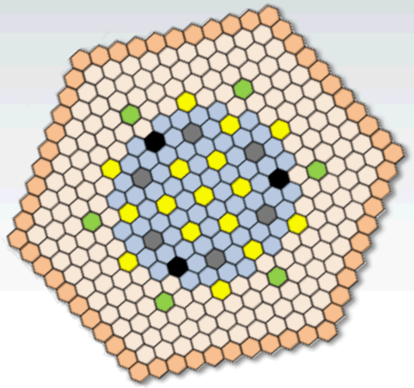
SMR operating by 2026

- Enable deployment through siting and technical support
- Joint Use Modular Plant leased for federal RDD&D



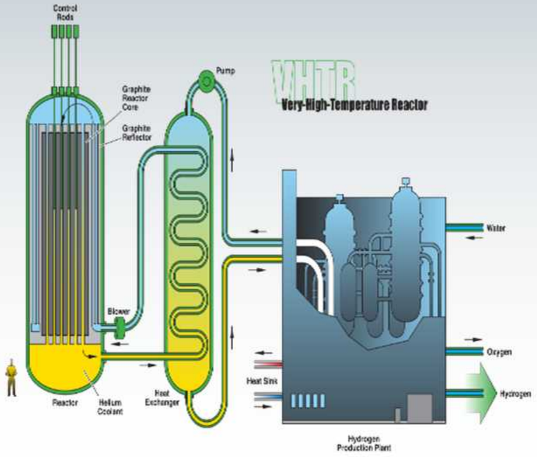
Versatile Test Reactor (VTR) operating by 2026

- Supported by micro-reactor demonstration
- Re-establish leadership in fast-spectrum testing and fuel development capability
- Support non-LWR advanced reactor demonstration



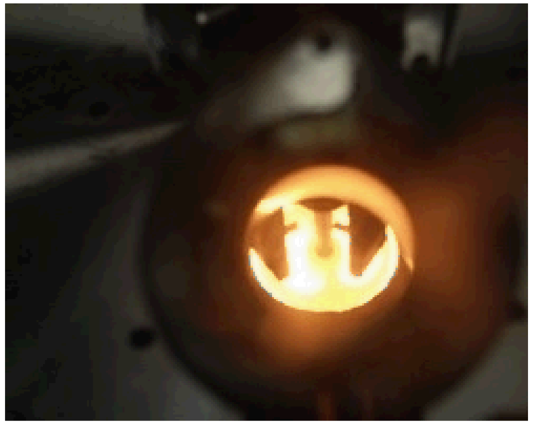
Non-LWR Advanced Demonstration Reactor by 2030

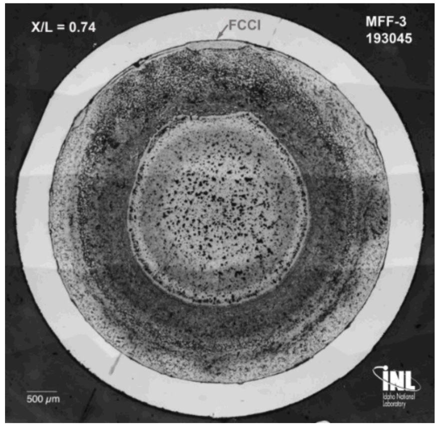
- Demonstrate non-LWR technology replacement of US baseload clean power capacity

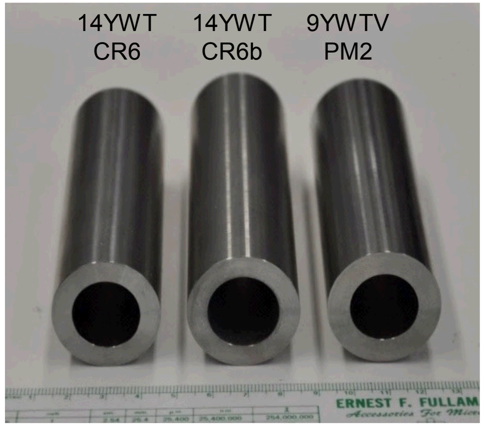


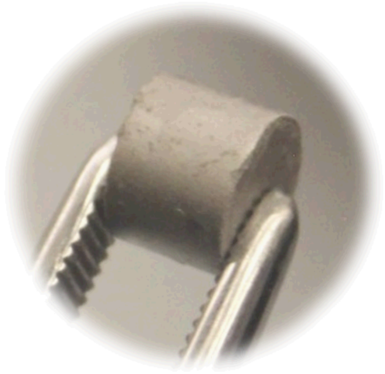
Advanced reactor fuels are needed for advanced reactors

- **Most advanced reactors require fuel/cladding systems that differ from those used in traditional light water reactors**
  - Physical form - metallic, mixed oxide, nitride, carbide, dispersion, coated particle, even liquid fuel
  - U-235 enrichment - 5-20%
  - Cladding - composites or coated materials
- **There is a need for U enriched between 5 and 20% (commonly referred to as High Assay Low Enrich Uranium [HALEU]) for advanced reactors development**
  - Currently there is no domestic capability









U_3Si_2 Pellet

INL R&D capabilities are being used to evaluate options for addressing HALEU needs

- **Commercial reactor concepts require HALEU for startup cores**
- **In addition, there are other national missions that require a reliable supply of enriched uranium**

Expected commercial demands for HALEU are very significant

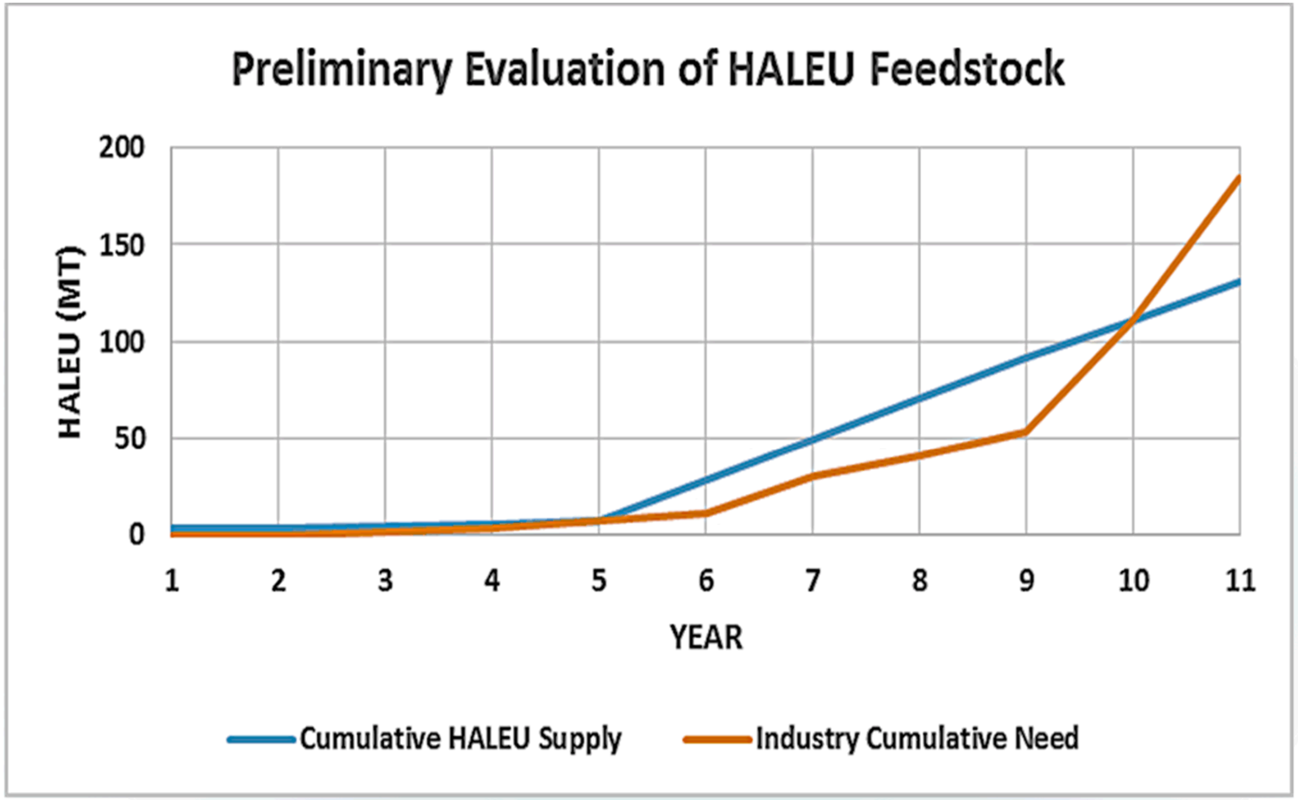
NEI Estimated Annual Commercial Requirements for HALEU to 2030 (MTU/yr)

Company	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Total**	**Cumulative**
Enrichment Range	13-19.75%	19-19.75%	10-19.75%	15.5%	19.75% and 12.6%	19.75%	17.5%	14.4%		
Year										
2018	0.001			0.025					0.026	0.026
2019	0.006	1.5							1.506	1.532
2020	0.7	1.5	0.01						2.21	3.7
2021	0.7	2.5				1.0			4.2	7.9
2022	0.7	3.0							3.7	11.6
2023	0.7	3.5	1.1		13.5				18.8	30.4
2024	0.7	5.0	1.1			3.0		0.5	10.3	40.7
2025	0.7	6.0	1.8	0.4		3.0		0.5	12.4	53.1
2026	23.3	7.0	1.8	0.4		3.0	21.4	0.5	57.4	110.5
2027	35.0	9.0	1.8	0.9		5.0	21.4	0.5	73.6	184.1
2028	46.6	11.0	1.8	1.8		25.0	21.4	0.5	108.1	292.2
2029	58.3	13.0	1.8	1.8		15.0	21.4	0.5	111.8	404.0
2030	70.0	13.5	1.8	1.8	61.0	15.0	21.4	1.0	185.5	589.5

https://www.nei.org/resources/letters-filings-comments/nei-letter-perry-need-haleu

INL HALEU R&D Program Objectives

- **Evaluate the feasibility of providing an interim supply of HALEU to support fuel-fabrication needs for R&D, and potential demonstration of advanced reactor concepts**
- **Support the development of HALEU infrastructure to include transportation, fuel fabrication, and advanced reactor testing**



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HALEU R&D Program Strategy

INL is looking into the feasibility of recovering and down-blending HEU from feedstocks with large ratios of HALEU/HEU that otherwise will be disposed at a cost to tax payers

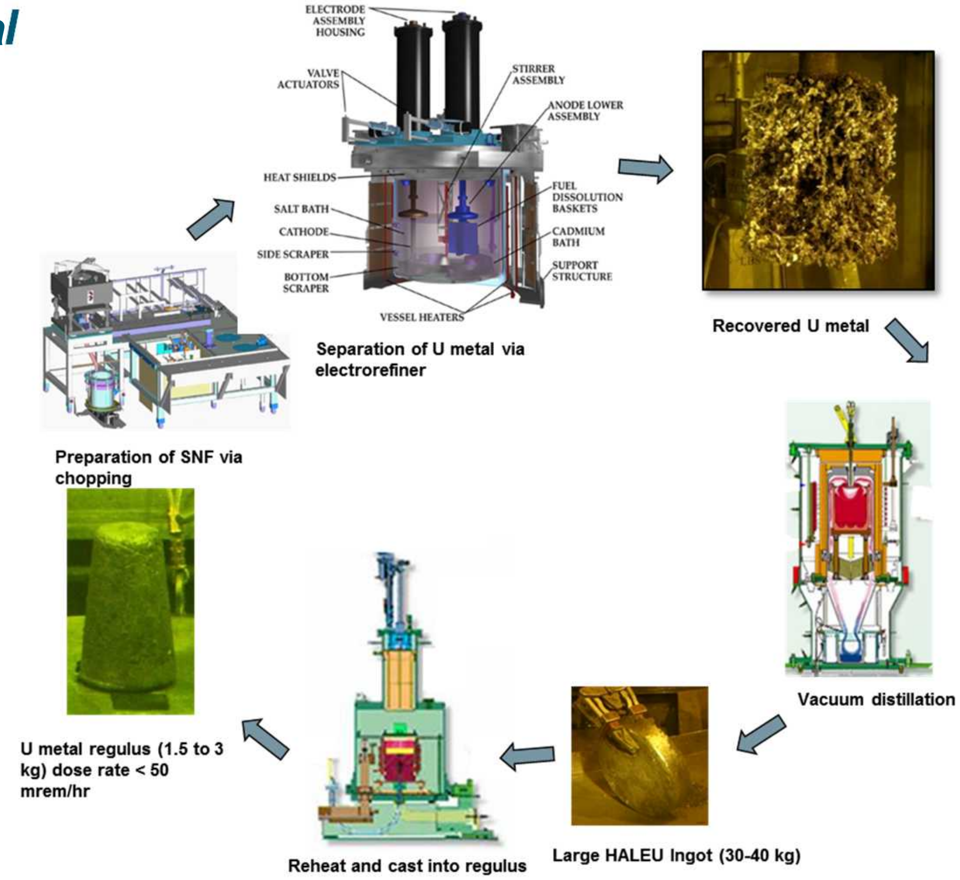
- **Possible feedstocks include end-of-life fuels from diverse irradiation origins**
  - EBR-II
  - Naval
  - Others (ATR, orphan irradiated materials, etc.)
- **Final HALEU form is determined by fuel specifications and fabrication needs**
- **Down-blending feedstocks varied and may include:**
  - 5% enriched LEU
  - Depleted Uranium
  - Natural Uranium
- **Recovery processes *(all available/under development at INL)* are determined by characteristics of the feedstock and may include:**
  - Electrochemical Process
  - Hybrid Process (ZIRCEX)
  - Others

Electrochemical separations process is being applied to EBR-II fuel treatment

Is a batch process that separates and recovers uranium metal from used HEU nuclear fuel and down-blends to HALEU

- **Step 1 – Irradiated HEU EBR-II fuel is prepared and placed into a high temperature molten salt electrorefiner which facilitates separation of U metal from fission products**
- **Step 2 – Recovered uranium undergoes vacuum distillation to remove electrorefiner salt and is down-blended to <20% U-235**
- **Step 3 – The recovered uranium metal is configured to serve as HALEU feedstock by reheating and casting into low-dose uranium metal ingots**

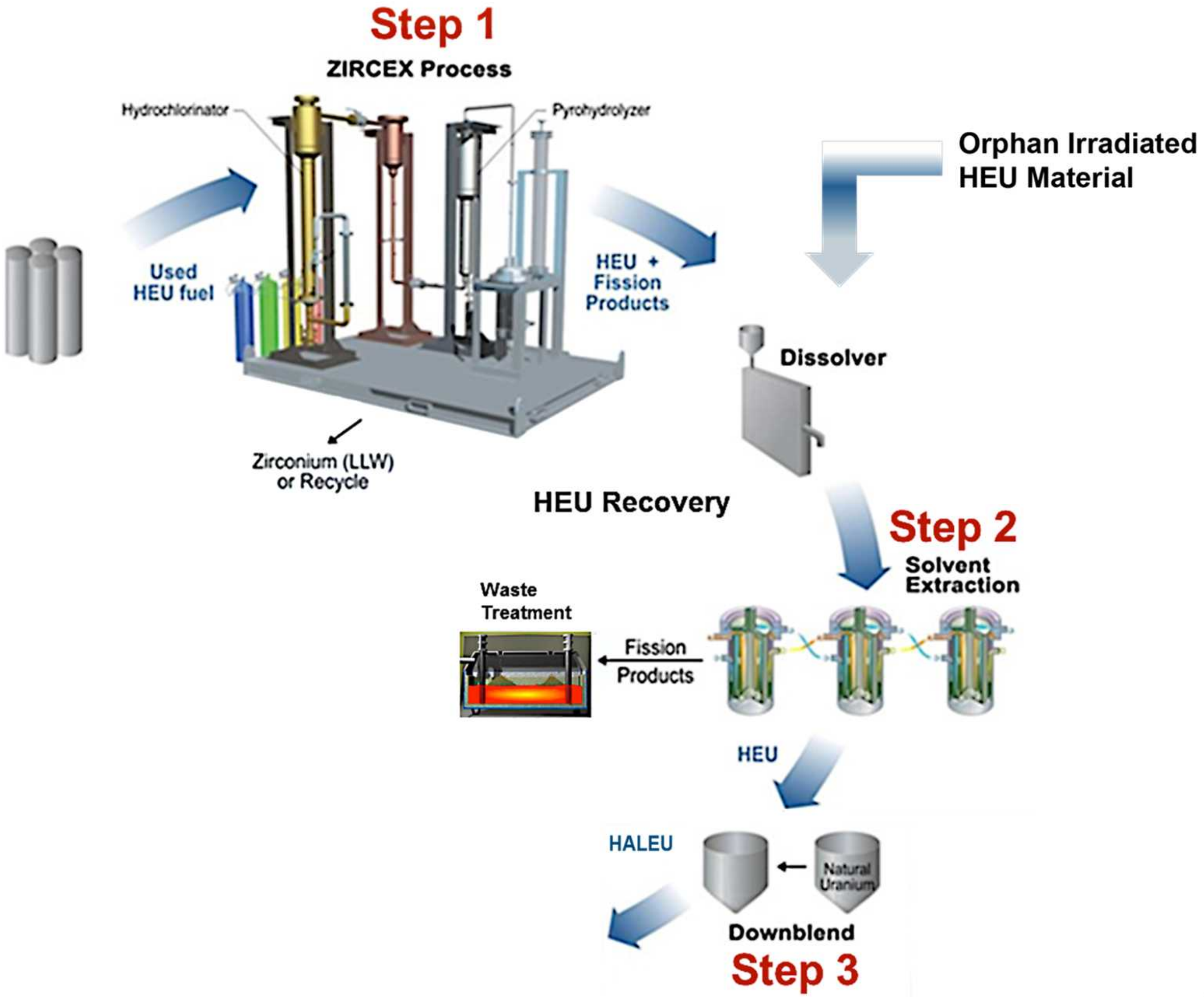
DOE is evaluating the environmental impact of this process and will be issuing a draft Environmental Assessment for public review and comment later this month



A hybrid (ZIRCEX) process is also being developed and evaluated

A three step process that recovers HEU from nuclear fuel and down-blends it to HALEU

- **Step 1 – ZIRCEX is a dry head-end process to remove cladding (zirconium or aluminum) from nuclear fuel**
- **Step 2 – Uranium is purified from fission products by a very compact, modular solvent extraction system. The fission products are immobilized in glass using a small in-can melt.**
- **Step 3 – The uranium is down-blended to <20% U-235 prior to fuel fabrication**



R&D ZIRCEX – Status

- Design, fabrication and installation of a ZIRCEX ¼ pilot plant scale system – completed
- Functionality testing – underway
- Approval to start R&D testing with zirconium expected during October 2018

Pilot Plant located at INTEC CPP-653

R&D FY19 – First Quarter Milestones

- **Complete staffing for alternatives study – October 30, 2018**
- **Initiate testing of surrogate fuel in ZIRCEX Material Recovery Pilot Plant – November 2018**
- **Begin engineering scoping studies to better understand issues, costs and schedule – November 2018**

Questions ?

Idaho National Laboratory